Int Marit Health
2023; 74, 1: 1–14
10.5603/IMH.2023.0001
www.intmarhealth.pl

ISSN 1641-9251
eISSN 2081-3252

VIA MEDICA

ORIGINAL ARTICLE

Working environment and fatigue among fishers in the north Atlantic: a field study

Annbjørg Selma Abrahamsen[1, 2], Ása Johannesen[3], Fróði Debes[1], Wessel M.A. van Leeuwen[4], Pál Weihe[1, 2]

[1]Department of Occupational Medicine and Public Health, The Faroese Hospital System, Tórshavn, Faroe Islands
[2]Faculty of Health Sciences, The Faroese University, Tórshavn, Faroe Islands
[3]Department of Technology and Environment, Fiskaaling, Hvalvík, Faroe Islands
[4]Department of Psychology, Stress Research Institute, Stockholm University, Stockholm, Sweden

ABSTRACT

Background: *This study investigates how Faroese deep-sea fishers' exposure to work-related stressors affects their sleep, sleepiness, and levels of fatigue. Being constantly exposed to the unpredictable and harsh North Atlantic Ocean, having long work hours and split sleep for up to 40 days consecutively, they will arguably suffer from fatigue.*

Materials and methods: *One hundred and fifty seven fishers participated in this study, and data was gathered throughout 202 days at sea. Subjective data was collected at the start and end of trips via questionnaires, sleep and sleepiness diaries and supplemented by objective sleep data through actigraphs. Ship movements were logged with a gyroscope connected to a laptop. A noise metre measured each work station and resting area, and noise exposure profiles were calculated based on each participant's activity and location. Linear mixed-effect models investigated the effects of work exposure variables on sleep efficiency, and cumulative link mixed models measured effects on the Karolinska Sleepiness Scale and physical fatigue scale.*

Results: *Time of day followed by ship movement were the exposure variables with the highest impact on the outcome variables of sleep efficiency, sleepiness and physical fatigue. The number of days at sea revealed correlations to outcome variables either by itself or interacting with the sleep periods per day. Crew size, shift system or noise did not impact outcome variables when in the model with other variables. Larger catches improved sleep efficiency but did not affect sleepiness and physical fatigue ratings.*

Conclusions: *The findings indicate a chronically fatigued fisher population, and recommends urgent attention being paid to improving the structure of vessels and installing stabilators for greater stability at sea; work schedules being evaluated for protection of health; and work environments being designed that fulfill human physiological requirements in order to ensure the wellbeing and safety of those at sea.*

(Int Marit Health 2023; 74, 1: 1–14)

Key words: fishers, work environment, roll, noise, fatigue, Multidimensional Fatigue Inventory-20 (MFI-20), Pittsburgh Sleep Quality Index (PSQI), Karolinska Sleepiness Scale (KSS), sleep, sleepiness, shiftwork

INTRODUCTION

The Faroe Islands is an archipelago situated in the North Atlantic Ocean with a population of around 54,000 people. The fishing and salmon farming industry are the backbone of the country's economy, with fish products making up 95% of total exports. Faroese fishers who participated in this

Annbjørg Selma Abrahamsen, MSc, Faculty of Health Sciences, The Faroese University, Vestarabryggja 15, FO-100 Tórshavn, Faroe Islands, e-mail: annbjorg@health.fo

Received: 7.11.2022 Accepted: 16.01.2023

study work in deep waters where challenging and unpredictable weather patterns often call for constant alertness in the areas of safety and balance. Despite declining accident rates in Scandinavian countries over the past decade [1–3], the accident rate amongst Faroese fishing crews is four times higher than that of land workers [1]. Studies have shown that fatigue is a problem amongst this group; and according to Wadsworth et al. [4], cognitive fatigue is the largest single factor contributing to the accidents (14%).

Occupational fatigue is proving to be a major problem in workplaces, with studies revealing its consequences as being especially damaging in the sectors of economy. Fatigue-induced work-related accidents in the United Kingdom alone are estimated to cost around £240 million a year [5] and costing 136.4 billion USD in lost productivity and healthcare costs [6]. The causes of fisher fatigue are the same as those observed amongst land-based workers, particularly when it comes to shift work. The most significant difference observed, however, is that those in the maritime sector are exposed to extra fatigue-inducing variables that are exclusive to sea-based operations in that their work takes place on constantly moving surfaces and in isolation from family, friends and familiar social activities. Furthermore, while usual work periods are limited to a single shift per day for work on land, split sleep (owing to multiple shifts per day) most often occurs at sea.

Within the realm of maritime operations too there are differences that impact the wellbeing of crews. During our data collection period, Faroese fishers were less protected against excessive working hours than workers on merchant fleets. Crews on merchant fleets were covered by the Maritime Labour Convention (MLC) legal obligations to get at least ten hours of rest per day divided into no more than two sleep periods, with a minimum of 77 hours of rest per week and a maximum of 14 hours of work per day. Crews on Faroese fishing vessel were not protected by the legal obligations of MCL, and were only entitled to 8 hours of rest per day. The usual working week of the fishers in this study was 84 hours or more, which often involved multiple shifts and sleep allocations that were usually broken into two or more periods a day. In a way, fishers might be better off than the maritime industry where it concerns the time being away from land [7], while factors, like the amount of fish defining working hours make the fishers worse off than the maritime industry, regarding this matter. It is important to note, however, that subsequent to our data collection, the laws pertaining to the rest hours for Faroese fishers changed as of 2021, bringing them under the protection of the MLC.

Crews on fishing vessels are more controlled by the catch than the clock, i.e., if the catch is good and they cannot load and store it within their stipulated work hours, they continue working until those on the next shift take over. This usually happened without fishers being granted compensatory rest periods. Thus, the fishers' work week gets longer and their rest periods more fragmented than that of their counterparts on merchant fleets. Additionally, the workload is typically high in ports and lower while at sea for crews on merchant ships [8], whereas the fishers' workload is more or less constant from the beginning to the end of trips with occasional extended hours expected of them if situations like vessel and equipment repairs or good catches call for it. Despite the decrease in working hours over the decades, the fishers' working day and week are still longer than for workers onshore. Additionally, manual handling of the fish, fishing methods and the quantity of the catch further influence the workload they carry [9].

The International Maritime Organization (IMO) defines fatigue as "a reduction in physical and/or mental capability as the result of physical, mental or emotional exertion which may impair nearly all physical abilities including strength; speed; reaction time; coordination; decision making; or balance." Work at sea might cause more fatigue than many other sectors ashore since working hours take place around the clock [10, 11].

Harsh weather conditions have adverse effects on the work environment at sea. Studies have shown that working on a moving vessel causes higher energy expenditure [12, 13]. Nevertheless, when studying the percentage of scores of seven or more on the Karolinska Sleepiness Scale (KSS) and the similar scale of physical fatigue (where ship movement was grouped into the three approximately same-sized groups of low, medium and high), roll and pitch seemed to have an instant preventive effect on the subjective feeling of sleepiness and physical fatigue. Fishers reported the lowest percentages of scores higher than seven — which is the marker for the risk of dozing off [14] — with middle roll and pitch, and often scored highest with low roll and pitch [15]. This in no way implies that roll and pitch do not cause fatigue but rather that higher ship movement forces fishers to be alert, and lower movement enables them to lapse into a state of relaxation. Åkerstedt et al. [16] support this explanation and point to the importance of the context, with participants reporting lower scores after activity and higher scores following rest periods.

Sleep disturbance due to noise has been rated as the major causal factor among 6-hour shift workers operating in the North Sea [17]. The World Health Organization (WHO) [18] states that disturbed sleep is the most frequently expressed complaint by noise-exposed populations, resulting in daytime sleepiness and lower functioning levels.

Shift work has been defined as work completed outside the usual 9:00 to 17:00 schedule from Monday to Friday [19]. Shift work disrupts the circadian rhythm, thereby causing sleep problems for many workers [20, 21]. A high

Table 1. Details of the vessel groups in this study

Vessel details	Longliner fresh fish	Longliner freezer	Netting vessels	Trawler	All
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Number of vessels*	6	1	3	5	15
Number of trips per vessel group*	8	1	3	5	17
Mean age of vessels	55.38 (5.18)	29	44.67 (8.96)	18.5 (9.65)	40.71 (18.4)
Building material	Steel	Steel	Steel	Steel	Steel
Gross tonnage	391.38 (32.98)	703	347.33 (58.18)	125.38 (6.04)	323 (158.1)
Breadth [m]	7.47 (0.06)	9	7.66 (0.82)	6.31 (0.46)	7.2 (0.9)
Depth [m]	6.17 (0.11)	4.4	5.26 (1.11)	3.3 (0.83)	5.1 (1.3)
Length overall	39.91 (2.90)	42	37.41 (1.47)	21.4 (1.68)	43.2 (8.8)
Engine power [kW]	487 (112.93)	745	618 (302.58)	344 (24.10)	484 (174.7)
Crew size	14 (1.30)	14	10 (0)	4 (0)	10.1 (4.3)

*The number of vessels and the number of trips do not add up because three trips were done onboard the same vessel, under different conditions. The first trip took place in summer when the fishing was good and the recommended work hours were exceeded. The second was conducted in another fishing area where the routines were different and the workload was lower; and the third happened closer to land with a small catch and many inexperienced deckhands, which required the implementation of another shift system (8 on, 8 off, 8 on, 4 off), leaving less time for rest; SD — standard deviation

work-to-rest ratio tends to cause poor circadian alignment and shorter sleep [15, 22]. The impact of shift work on sleep, sleepiness and performance seems to be mediated by: (i) circadian effect or time-of-day; (ii) hours at work (as against the opportunity for sleep); and (iii) the consistency of start and finish time [23]. Moreover, 81% of fishers claim that their sleep problems are limited to times at sea [17]. Given the choice, most would opt out of shiftwork [24].

The aim of this study is to investigate whether ship movement, noise, workload, work and rest schedules, ship variables and the number of days at sea over the preceding 12 months could be associated with fisher fatigue.

We hypothesised "sleep efficiency," measured by the ActiGraph, as being positively impacted by: 1a) ship variables such as vessel size and engine power; 2a) crew size; 3a) size of catch per day; and 4a) number of days at sea; and being negatively impacted by 5a) the weather (causing ship movement, pitch and roll); and 6a) noise during work and rest time. We also surmised that 7a) that different shift systems have different effects on sleep efficiency. Similarly, we hypothesised that sleepiness as measured by the KSS and fatigue measured by a Physical Fatigue Scale (PFS) will be positively impacted by: 1b) ship variables such as vessel size and engine power; and 2b) crew size, which will have a protective effect on the KSS and physical effect, with ratings decreasing as vessel and crew size grew larger. We surmised KSS and PFS scores being adversely impacted by: 3b) the weather (causing ship movement, pitch and roll); 4b) noise during work and rest time; 5b) number of days at sea; 6b) size of catch per day; and 7b) different shift systems will have different effect on KSS and PFS.

MATERIALS AND METHODS

DESCRIPTIVE STATISTICS

Data were collected onboard four vessel groups in the Faroese deep sea fishing fleet from May 2017 to July 2018 off fresh fish longliners, freezer longliners, small trawlers and netting vessels. The details of these vessels are given in Table 1.

Of the 176 fishers who were invited to participate in the study, 89.2% (comprising 156 men and one woman) agreed to do so. When responding to the question about overall health, 91.8% stated that they were in excellent, very good or good health, thus implying that they were generally healthy. Their mean age was 42.2 (standard deviation [SD] 16.3) years. Data collection took place mainly onboard the vessels from the time they left harbour to the last day of fishing before they returned. The fishers also completed sleep and sleepiness registrations in diaries throughout the entire trip. Data and observations onboard the vessels were collected by the first author. A questionnaire collecting demographic data about their work, work history and various psychometric questionnaires were used.

SHIP MOVEMENT

Ship movements were logged throughout the entire trip using a gyroscope (30 × 30 × 20 cm) with two inbuilt sonar sensors (Taeko scl-30a1, Foruna Industries, Esbjerg). It was positioned in the wheelhouses near the centre of the ship. The gyroscope was connected to a laptop and registered ship movement on two planes: rolls from side to side and pitch from fore to aft. PicoLog, Pico Technology, provided the computer software (PicoLog data acquisition software/data logging software, n.d.).

NOISE LEVELS

Noise levels were typically measured during a whole shift per working station while the periods of measurement were sometimes shorter for resting areas. We used a Casella SEL-633 Environmental and Occupational Noise Meter for measurement (www.casellameasurement.com). Noise exposure profiles in decibel level dB(A) were calculated per person based on knowledge about their individual duties, rotational systems and the decibel levels measured in each station. Details of noise per vessel are listed in Table 2 together with environmental exposures.

SLEEP MEASURES BY ACTIGRAPHY

Wrist-worn actigraphs (ActiGraph GT9X link; Pensacola, FL, USA) were used as an objective measure of sleep and activity. Various sleep variables were obtained from the ActiGraphs: total number of sleep periods, mean number of sleep periods per day, mean sleep durations per day and sleep efficiency (defined as the percentage of time spent sleeping in bed). The Cole-Kripke algorithm was used to estimate the sleep parameters [25]. Further information on the results concerning sleep is referred to in our earlier work [15].

SLEEPINESS MEASURES AND PHYSICAL FATIGUE SCALE

The KSS [26], ranging from 1 (very alert) to 9 (extremely sleepy) was used to measure sleepiness during the trip. A similar physical fatigue scale, also ranging from 1 to 9, with 1 (very rested) and 9 (extremely physically fatigued) was also present in the diary. Fishers were instructed to register their sleepiness and physical fatigue in diaries provided to them at least every two hours while at work.

SLEEP QUALITY

The Pittsburgh Sleep Quality Index (PSQI) is a questionnaire which measures long-term sleep quality [27]. The PSQI score was used as a subjective measure of a more general level of sleep quality; and the Multidimensional Fatigue Inventory-20 (MFI-20) exploring five factors: general fatigue, physical fatigue, mental fatigue, reduced activity and reduced motivation with a 5-point Likert scale (1–5) was used to measure the fishers' level of fatigue at the beginning of the trip [28].

WORK EXPOSURE VARIABLES

Variables regarding the fishers' work exposure included the catch in tons per person per day, shift system, crew size, length of the trip and days at sea per year. The fishers were identified by ID numbers, and variables measured were subjective ratings of sleepiness, physical fatigue, objective sleep variables measured by the actigraphy, time of day of sleep, length of sleep and sleep efficiency.

VESSEL VARIABLES

Variables concerning the ship were: vessel type, age of vessel, building material, size in gross tons, length, breadth and engine power in kilowatts (kW).

ANALYTICAL METHODS

Analyses were conducted using RStudio 4.2.1 (RStudio Team, 2020). RStudio: Integrated Development for R. RStudio, PBC, Boston, MA (URL http://www.rstudio.com/), with the packages tidyverse [29], readxl [30], hms [31], lme4 [32], lmerTest [33], clmm [34], nlme [35] for data manipulation and analysis, and colourspace [36] and gridextra [37] for creating figures.

Mean and standard deviation from the PSQI and MFI-20 were explored using SPSS 25, after which a linear mixed model analysis was run on sleep efficiency against ship movement variables, noise, work exposures and various ship variables.

The linear mixed effects model was defined using crew ID nested within vessel type as random intercepts to investigate sleep efficiency and how it was affected by environmental variables. Sleep efficiency was the outcome variable in the model. Additive predictor variables were pitch, roll, catch per person per day in tonnes, engine power, as well as a dummy variable designating a time of day when the crew went to bed which was constructed using the following time points: morning (06:30 to 12:30), day (12:30 to 18:30), evening (18:30 to 00:30) and night (00:30 to 06:30). An interaction term with the number of days at sea crossed with the mean number of periods of sleep per day prior to the observation was also included.

Cumulative link mixed models were used to investigate the effects on the ordinal variables KSS and physical fatigue. Models were constructed in a similar way to the investigation on sleep efficiency.

The KSS and the PFS were reported every second hour during the trip. The frequent recordings made them an excellent measure of the fishers' subjective fatigue level per day (acute fatigue), and suitable for uncovering the relationship between environmental variables (that vary daily) and fatigue. Because KSS and the PFS are ordinal variables, cumulative link mixed models were used to investigate how these measures were affected by the same predictor variables tested in the linear mixed effects model.

Several measured variables were excluded as they did not affect sleep efficiency, KSS and PFS, or were too related to other terms, thus making them difficult to interpret. Therefore, the models in Tables 5 and 6 are the smallest adequate models to describe the effects on the outcome variables.

The impact of noise on the three outcome variables, sleep efficiency, KSS, and PFS was investigated separately

Table 2. Descriptive statistics of the crews divided into vessel groups

	Longliner fresh fish	Longliner freezer	Netting vessel	Trawler	Overall
	Mean (SD)	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Number of participants	90	14	29	19	152
Captain	7	1	3	5	16
Mate	9	1	3	5	17
Engineman	8	1	3	4	16
Cook	8	1	3	2	14
Deckhand	51	8	17	3	79
Holdman*	7	2			9
Minutes slept per sleep	149.3 (48.1)	220.6 (56.2)	198.9 (63.7)	117.7 (50.0)	161.9 (60.4)
Minutes slept per day	278.8 (76.3)	332.5 (40.8)	250.3 (94.9)	233.4 (80.2)	272.3 (81.8)
Body mass index	26.3 (5.6)	27.9 (6.1)	25.7 (4.8)	29.0 (4.4)	26.7 (5.3)
Age	42.4 (1.7)	36.3 (15.4)	41.5 (15.4)	46.4 (15.2)	42.1 (16.1)
Work years as a fisher	25.1 (14.1)	17.7 (18.2)	17.6 (16.2)	27.8 (15.2)	19.5 (16.3)
Mean workdays a year:	199	189	187	204	196
Minimum days	15	39	50	100	15
Maximum days	320	340	300	340	340

*On netting vessels, the mate takes care of getting the fish down to the hold, while on trawlers it is a deckhand who undertakes the task; SD — standard deviation

with a linear mixed model for sleep efficiency and by using a cumulative link mixed model for the analysis of the other two outcome variables: KSS and PFS.

We defined a linear mixed effects model using vessel as random intercept. Noise during work, time off, and all day (24-hours) in interaction with the use of earmuffs were included as fixed effect variables on sleep efficiency. This process was repeated with the KSS and the PFS run separately but using a cumulative link mixed model ANOVA to examine the differences between the vessel types on the time-of-day variable.

RESULTS

DESCRIPTIVE STATISTICS

Table 2 gives an overview of the composition of the crews in the four vessel types. Furthermore, age, body mass index, years in fishing occupation and days at sea during the last year are reported groupwise.

Table 3 summarises the recorded results regarding noise exposure, ship movements, weather conditions and catches in the four vessel categories together and separately.

FATIGUE MEASURED AT THE BEGINNING OF THE TRIP

The MFI-20 revealed that the fishers experienced high fatigue on all five MFI-20 factors. The overall means were: 12 (SD 2.3) for general fatigue, 9.5 (SD 2.1) for physical fatigue, 9.2 (SD 2.1) for mental fatigue, 9.2 (SD 3.1) for reduced activity, and 7.7 (SD 2.6) on reduced motivation. See Table 4 for scores of the specific vessel groups.

LONG-TERM SLEEP QUALITY

Long-term sleep quality explored with the PSQI revealed that the current fishers have poor sleep quality, with an overall score of 9.36 (SD 3.48), where a score > 5 indicates poor sleep. This score varied between the vessel groups, with fishers on netting vessels (n = 29) being the only crews that slept only at night and who also worked the longest consecutive hours having the lowest mean score, 8.01 (SD 3.43). The fishers on the freezer longliner (n = 14), who rotated 8-on, 8-off, working every second night from 20:30 to 04:30 had the highest mean of 10.37 (SD. 3.15). The other two groups scored 9.88 (3.70) and 8.51 (1.55) for longliner fresh fish and trawler boats respectively.

WORKING ENVIRONMENTAL IMPACT ON SLEEP EFFICIENCY

The preliminary analysis showed that after dealing with collinearity and lack of variance and adding all factors into the same model, engine power was the only ship variable to add explanatory value to the model.

Table 3. The environmental exposures of the fishers in mean and standard deviation (SD)

Environmental variables	Longliner fresh fish	Longliner freezer	Netting vessel	Trawler boat	Overall
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
dB(A) work	87.70 (9.52)	85.5 (7.80)	83.64 (6.90)	85.79 (8.80)	86.79 (6.62)
dB(A) time-off	66.47 (5.05)	71.07 (2.46)	73.03 (3.30)	69.26 (4.68)	67.37 (6.29)
dB(A) for 24 h day	84.84 (8.77)	83.3 (6.92)	82.06 (6.46)	83.16 (8.03)	82.65 (8.66)
dB (A) differences between work and time off	21.23 (11.47)	14.43 (7.41)	10.61 (6.78)	16.53 (10.73)	16.79 (10.8)
Mean roll	3.9 (0.59)	3.9 (0.0)	3.3 (1.19)	3.3 (0.87)	3.8 (0.87)
Max roll	59.10 (8.6)	33.6 (0.0)	39.8 (9.8)	59.1 (9.8)	59.1 (11.2)
Mean pitch	2.6 (1.54)	1.8 (0.0)	4.2 (1.99)	4.1 (3.31)	3.1 (2.0)
Max pitch	43.6 (9.8)	29.8 (0.0)	39.0 (10.2)	56.2 (10.7)	56.2 (9.8)
Mean wind [m/s]	10.11 (2.31)	11.47 (3.75)	10.34 (4.04)	9.31 (0.54)	10.23 (2.66)
Frequency (%) of days with winds ≥ 15 m/s	23.45 (16.03)	25 (0.00)	15.18 (14.42)	19.43 (10.24)	21.39 (14.84)
Mean catch in kilos per man per day	340.0 (305.4)	540.0 (182.6)	277.86 (135.4)	989.6 (503.8)	430.3 (339.8)

dB(A) work — decibel during work; dB(A) time off — decibel during time off; dB(A) for 24h day — mean decibel throughout the day; roll — ship movement from side to side, pitch — ship movement from fore to aft

Table 4. The fishers' scores in mean and standard deviation (SD) on the Multidimensional Fatigue Inventory-20 (MFI-20)

MFI-20 factors	Longliner fresh fish	Longliner freezer	Netting vessel	Trawler	Overall
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
General fatigue	12.1 (2.4)	13.0 (2.2)	11.8 (2.3)	11.2 (2.1)	12 (2.3)
Physical fatigue	9.9 (2.0)	9.4 (2.7)	9.1 (1.9)	8.7 (2.1)	9.5 (2.1)
Mental fatigue	9.4 (2.1)	8.6 (2.1)	9.4 (1.9)	8.8 (2.6)	9.2 (2.1)
Reduced activity	9.4 (3.2)	8.2 (2.7)	8.9 (3.3)	10.4 (3.1)	9.2 (3.1)
Reduced motivation	8.1 (2.7)	6.6 (2.3)	7.6 (2.5)	6.8 (2.1)	7.7 (2.6)

After taking out non-significant and highly correlated variables, the results from the linear mixed model displayed in Table 5 for sleep efficiency is the minimal model to describe which variables have the highest influence on the fishers' sleep.

From this model, we see that roll, catch per person per day and the time of day the person sleeps having the highest impacts on sleep efficiency, with sleep during the day shift and night shift offering higher sleep efficiency than sleeping during the morning (06:30 to 12:30). The interaction between the number of sleep periods and the length of the trip shows a negative effect. Figure 1 demonstrates just how these two variables interact.

When not controlling for other confounding variables, the mean sleep efficiency throughout the trip is highest among freezer longliners (M = 71.7, SD = 15.8) and lowest for fresh fish longliners (M = 62.8, SD = 23.3). For trawlers and netting vessels, the sleep efficiency was 67.1 (SD = 23.8), and 68.7 (SD = 20), respectively. When examining sleep efficiency, we see a more complex picture when simultaneously controlling for the length of trip and the number of sleep periods per day. Periods of sleep in a day and number of days at sea interacted such that crew with many periods of sleep within a day had a decreasing sleep efficiency over time compared to workers who had fewer sleep periods in a day ($F_{1,2205.8}$ = 7.449, p = 0.006, Fig. 1).

WORKING ENVIRONMENTAL IMPACT ON SLEEPINESS

As for the cumulative link mixed models, the first one reveals that the KSS has only one significant relation-

Table 5. Effect of environmental variables on sleep efficiency

Effect	Estimate	SE	P-value
Intercept*	62.31	45.65	< 0.001
Roll	–3.45	0.006	< 0.001
Pitch	–0.82	–0.26	< 0.001
Engine power of ship [kW]	0.026	0.006	< 0.001
Catch-per-person-per-day [T]	3.65	1.43	0.01
Time of day (06:30–12:30 functioned as the reference variable			
12:30–18:30	3.48	1.31	0.007
18:30–00:30	0.10	1.1	0.93
00:30–06:30	4.16	1.27	0.001
Sleep periods per day	1.41	1.48	0.34
Days at sea	0.69	0.30	0.02
Interaction: Sleep periods per day and days at sea	–0.46	0.19	0.02

[a]Intercept — baseline of sleep efficiency; Sleep efficiency — outcome variable. Exposure variables are: Roll, pitch, catch per person per day in tonnes, engine power, and the dummy variable designating a time of day when the crew went to bed, using the time points: morning (06:30 to 12:30, day (1230 to 18:30, evening (18:30 to 00:30 and night (00:30 to 06:30 as additive predictor variables. The interaction consists of the number of days at sea crossed with the mean number of periods of sleep per day prior to the observation. The estimate shows the effect of the exposure variables on the output variable (sleep efficiency. The standard deviation of an estimate is called the standard error (SE. The standard error of the coefficient measures how precisely the model estimates the coefficient's unknown value.

ship to the independent variables — the length of the trip (p = 0.045), with an increase on the KSS scale of 0.007 for every additional day at sea.

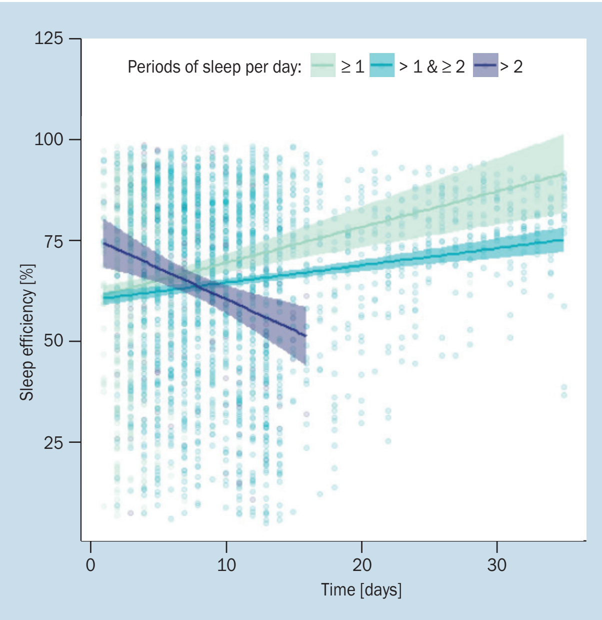

Figure 1. Sleep efficiency over days at sea. Colours signify mean periods of sleep per day: few — up to and including one sleep period per day, middle — more than one, up to and including two sleep periods per day, many — more than two sleep periods per day. Dots indicate observations, lines are lines of best fit with 95% confidence interval shaded

WORKING ENVIRONMENTAL IMPACT ON PHYSICAL FATIGUE

Physical Fatigue Scale, on the contrary, demonstrated a few more relationships to the predictor variables with the time of day and, in particular, the morning and day shift displaying significantly lower fatigue ratings than night shifts (Table 6, Fig. 2).

TIME OF DAY AND SLEEPINESS

Since the time of day showed the strongest effect on sleep efficiency and physical fatigue (Tables 5 and 6), a cumulative link mixed model was run between KSS and time of day, with ID nested within vessel type to view the relationship between these two variables when not controlling for other factors. It was found that sleepiness was highly associated with the time of day, with lower registrations of sleepiness between 06:30 and 12:30, z = –8.27, p < 0.001, 12:30 to 18:30, z = –9.21, p < 0.001, and 18:30 to 00:30, z = –2.81, p = 0.005 respectively, in comparison to the hours between 00:30 to 06:30.

VESSEL TYPE DIFFERENCES REGARDING PHYSICAL FATIGUE AND SLEEPINESS

Lastly, the mean score on the KSS and the PFS also varied across vessel types, ANOVA = (F(3,29.5) = 102.89, p < 0.001) and (F(3, 50.43) = 152.21, p < 0.001), respectively. For the difference between the vessel groups measured with the Bonferroni post hoc test (Table 7).

Table 6. Impact of environmental variables on ratings on the Physical Fatigue Scale (PFS, 1–9) from the cumulative link mixed model

Effect	Estimate	SE	P-value
Mean roll	0.05	0.02	0.02
Mean pitch	0.05	0.02	0.007
Time of day (00:30–06:30 functioned as the reference variable)			
06:30–12:30	–0.44	0.07	< 0.001
12:30–18:30	–0.042	0.07	< 0.001
18:30–00:30	0.06	0.07	0.42
Days at sea	–0.02	0.004	< 0.001

Physical Fatigue Scale (PFS) — outcome variable. Exposure variables with significant effects on outcome variable are: roll, pitch, the dummy variable designating a time of day using the time points: morning (06:30 to 12:30), day (12:30 to 18:30) and evening (18:30 to 00:30) as additive predictor variables, as against night (00:30 to 06:30) used as reference variable and the number of days at sea. The estimate shows the effect of the exposure variables on the output variable (sleep efficiency). The standard deviation of an estimate is called the standard error (SE). The standard error of the coefficient measures how precisely the model estimates the coefficient's unknown value.

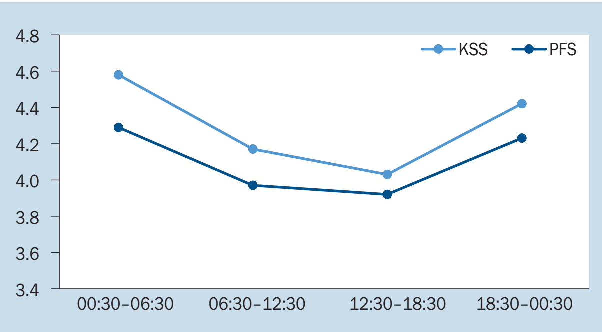

Figure 2. Mean level of sleepiness (Karolinska Sleepiness Scale [KSS]) and physical fatigue (Physical Fatigue Scale [PFS]) registered over the day, divided into four time points: night (00:30 to 06:30), morning (06:30 to 12:30), day (12:30 to 18:30) and evening (18:30 to 00:30)

NOISE AND SLEEP EFFICIENCY

Noise during time off had a positive relationship to sleep efficiency ($F_{1, 145.5} = 12.30$, $p < 0.001$, confidence interval [CI] = 0.33 to 1.21), with efficiency increasing by 0.78 points per increase in dB(A). No relationship was found between sleepiness and noise during time off, although a trend was observed that showed that dB(A) had a negative relationship to sleepiness (estimate = 0.04, standard error [SE] = 0.22, df = 80.09, t = 1.495, p = 0.055, CI = –0.09 to 0.01). Similarly, physical fatigue did not show any relationships to noise during work although the trend between noise and physical fatigue were close (estimate = 0.02, SE = 0.013, df = 108.87, t = 1.90, p = 0.06, CI = –0.002 to 0.050).

DISCUSSION

Data regarding the fishers' working environment were collected for this study from four types of fishing vessels to elucidate how the work environment influenced their fatigue while at sea by investigating their sleep (quantity and quality), sleepiness, physical fatigue, ship movement and noise levels; as well as by examining the effect of crew size, weight of catch in tons, vessel type, shift system, hours worked per day, time of day and length of trip.

For the 15 months of data collection, the catch was generally poor. Only one trip during this entire period had frequent, extended shifts for fishers. Insufficient catches created stress owing to the low income that would be generated from them, and overshadowed entire trips especially in the case of longliners. In one instance, the trip was called off halfway because the amount of fish caught did not cover the expenses incurred. The catch on trawlers was moderate, leaving more time for rest than work although rest was split into multiple rest periods. However, there was one particular season when the catch on trawlers was so good that workers filled up their vessels in 24 to 36 hours. During this period, a loaded trawler ran aground on the way back to land. It was not possible for the first author to personally observe these trips because there was no room on the vessels owing to the load. Overall, the data collection period saw relatively low workloads, thus the results reflected are realistic or milder than most periods.

Hypothesis 1 about ship variables showed that only the ship's engine power — seen as a good overall representation of the ship size (length, breadth, depth) — correlated positively with sleep efficiency thus accepted the hypothesis 1a, but did not reveal any effect on KSS or physical fatigue scores, thereby rejecting this hypothesis 1b. Hypothesis 2 was also confirmed with higher ship movement increasing physical fatigue and decreasing sleep efficiency. Hypothesis 3 regarding the effect of noise was rejected as noise during time off correlated positively with sleep efficiency. Contrary to expectation, hypothesis 4, which was about the effect of shift systems, was also rejected since no significant impact was revealed between shift systems and the outcome variables, sleep efficiency, sleepiness

Table 7. Scorings on the Karolinska Sleepiness Scale (KSS) and Physical Fatigue Scale (PFS) as a function of vessel type analysed by ANOVA and Bonferroni post hoc test

Scores on KSS and PFS vs vessels	Measurements (N)	Mean	SD	P-value
KSS score across vessel types				
Netting vessel vs.	558	5.00	2.12	
Longliner fresh fish	3639	4.27	1.92	< 0.001
Trawler	439	4.22	2.03	< 0.001
Longliner freezer	1998	4.17	1.63	< 0.001
All vessels	6634	4.30	1.88	< 0.001
PFS across vessel types				
Netting vessel vs.	558	4.92	2.03	
Longliner fresh fish	2839	4.03	1.79	< 0.001
Trawler	439	3.74	2.07	< 0.001
Freezer longliner	1999	4.05	1.47	0.96
Longliner fresh fish vs.	2839	4.03	1.79	
Trawler	439	3.74	2.07	0.006
Freezer longliner	1999	4.05	1.47	0.96
Trawler vs.	439	3.74	2.07	
Freezer longliner	1999	4.05	1.47	0.003
All vessels	5833	4.10	1.76	< 0.001

or physical fatigue. Hypothesis 5 was rejected with no relationship observed between crew size and the outcome variables. Hypothesis 6a and 6b were also dismissed as it revealed a pattern opposite to what was predicted, with catch-per-person-per-day showing a strong positive relationship with sleep efficiency, and no relationship to KSS and PFS. Lastly, the hypotheses 7a and 7b about the number of days at sea revealed a positive impact on sleep efficiency but a negative impact on PFS, thus rejecting hypothesis 7a regarding sleep efficiency but confirming hypothesis 7b about physical fatigue.

Fatigue and low sleep quality were problems for fishers as observed by the scores of the MFI-20 and the PSQI. This was expected as the fishers either had split sleep with up to 3 to 4 sleep periods a day, or long working hours of up to 18 hours a day. When comparing the current fishers' scores on the MFI-20 to a study of Danish fishers [38], the Faroese fishers scored significantly higher on all scales of the MFI-20 as well as when compared to the Danish population in two cross-sectional studies [39, 40]. There are a few factors that could explain these differences, the most apparent one being that the trip lengths of Danish fishers are lower overall, with 48.1% of the trips lasting only a day, 34.9% lasting between 1 and 7 days, and only 17.1% spending more than 7 days at sea in comparison to the Faroese fishers with a mean of 10.7 (SD 8.8) days. Since the largest category of Danish fishing trips last only a day, sailors most probably fish in calmer seas closer to land unlike Faroese fishers who sail into the North Atlantic Ocean for extended periods of time.

The results from the PSQI further reveal that the fishers generally had poor sleep quality, with a mean score of 9.4, which is significantly higher than the cut-off for poor sleep (> 5). In comparison, when considering a study conducted on 147 healthy participants, the mean score of the group with insomnia (46.3%) was 10.65 ± 2.79 when compared with 2.63 ± 1.29 for the non-insomnia group [41]. Although the crews of the freezer longliners reported the worst sleep quality according to the PSQI, they reported the lowest level of sleepiness on KSS during trips, and had the highest sleep efficiency. Possibly the low score on the PSQI is because the rhythm is longer than the approximate 24 hours of the biological clock, which is in line with the findings of Short et al. [23], who point to the mediating effect of the time of day and the consistency of start and finish times. However, this rhythm ensured that they got a long night's sleep every second night, making the connection between the fishers and their shifts less dependent on chronotype.

In the larger model used for testing the effect on sleep efficiency (Table 5), the time of day the fishers slept had the highest impact. Fishers slept worst in the morning (06:30 to 12:30) and best during the night (00:30 to 06:30). Roll and pitch had the second largest influence on the decrease in fishers' sleep efficiency, with substantial reductions observed with increased ship movement.

Of the individual ship variables, the size of the ship's engine showed a positive relationship to sleep efficiency. We see the engine as a usable proxy for the overall size of the ship rather than separate measures of length, depth and breadth. This finding is consistent with studies confirming that weather influences smaller vessels more than larger vessels [9].

Catch in tons per person per day showed a substantial impact on improving sleep. A larger catch meant more work for the fishers which required more use of energy thereby enhancing sleep, presumably by increased sleep pressure. Furthermore, substantial harvests of fish generally resulted in mental satisfaction since fishers know that they bring in better wages, thus relieving them of stress and uncertainty and consequently increasing sleep efficiency. These too are possible reasons for greater sleep efficiency in workers at sea.

Lastly, several studies have pointed to the adverse effects of splitting sleep into smaller amounts of time [15, 42, 43]. Our study confirms this through an interaction effect, with the number of sleep periods per day and the trip length showing a negative relationship with sleep efficiency. Getting more extended uninterrupted periods of sleep per day seemed to enhance sleep efficiency which increased with every additional day at sea. This interaction demonstrates the level of complexity to be considered in order to comprehend the potential factors from work environments that contribute to the build-up of fatigue among these fishers. On the other hand, the increase in sleep efficiency could also indicate increasing levels of fatigue as the trip progressed, which also results in higher sleep efficiency. Most likely, the answer is a combination of the two. Netting vessel crews are the only ones who get one continuous sleep period, who sleep only during the night and also have a higher work-rest ratio of 16-hours/8-hours respectively when compared with the other vessel groups. Thus, the steep increase in sleep efficiency may partly be due to excessive fatigue since this vessel group has the highest work-rest ratio. Taking all these factors into consideration, caution should be exercised in interpretations of the difference between the groupings when it comes to "sleeping once a day or less," and "sleeping more than once a day but no more than twice a day."

In the model with sleepiness as the outcome variable, the only relationship was with the number of days at sea, with sleepiness increasing as the trip grew longer. Our study supports the findings of the diurnal pattern of sleepiness being U-shaped, with higher KSS values in the early morning and late evening [44].

When considering physical fatigue scale as an outcome variable but otherwise including the same exposure variables, the cumulative link mixed model results supported the finding of Short et al. [23], with fisher's reporting highest on fatigue during the circadian nadir. A strong circadian variation has been found in sleepiness, with sleepiness peaking at night [22, 45, 46]. Our study confirmed these findings as well. The time of day was the strongest indicator of self-reported sleepiness and physical fatigue, with the highest number being reported during the evening and night shifts. This confirms many other research studies found in circadian literature about shift workers [23, 47, 48].

Roll and pitch also impacted physical fatigue ratings with more ship movement leading to higher ratings, confirming studies which indicate that ship movement leads to higher metabolic rate and exhaustion; thus, likely having a secondary effect on sleep efficiency as well [12, 13].

Findings from studies about noise frequency conclude that noise has a negative effect on sleep [17, 49, 50]. However, only a few studies have used objective measures of noise onboard vessels [51, 52]. In the current study, noise exposure was not found to impact the fishers' sleep, sleepiness or fatigue levels when analysed together with the other main variables that added significant explanations to the model. When analysed as single variables, the relationship between sleep efficiency and noise was positive. Most fishers in the current study used earmuffs for hearing protection during work which reduced the noise level by at least 20 dB(A), but did not use them during their time off. Therefore, the noise level during work cannot be expected to reflect their actual exposure as fishers were more likely to use earmuffs in locations with the highest noise. Our questionnaires only required them to indicate whether they had used them during the trip or not. Furthermore, the finding that sleep efficiency increased as the noise increased could be explained by their cumulated fatigue — partly due to noise exposure during the day — which made them sleep better. We only used average noise levels in dB(A) in our analysis and did not include peak exposures and frequencies of the sound. Although the levels recorded in the current study are high, they are relatively constant. Atkinson and Hilgard (1983) [53] claim that "people are much more able to 'tune out' chronic background noise, even if it is quite loud, than to work under circumstances with unexpected intrusions of noise." The reason why we only found significant relationships during time off but not during work may be because the range from the lowest score to the highest score was higher during time off than at work. Thus, the variance is too limited in the noise levels at work to produce significant results. Despite their insignificance, the trends between physical fatigue and noise at work, and between sleepiness and noise during time off went in predicted directions when analysed as single variables.

It was somewhat surprising that of all the ship's variables (i.e., ship age, length, breadth, depth, gross tonnage, and engine power), only engine power was associated with sleep efficiency in the combined model (Fig. 5). The variance in the engine power of the ships was higher than the variance in the other ship variables, and could be one reason for the findings.

The Cardiff Research Programme of Seafarers' Fatigue [43] states that it is the combination of risk factors that exposes the greatest fatigue, and that the effect of additional risk factors increases fatigue in a cumulative manner. The fishers in the current study were repeatedly exposed to adverse risk factors such as disturbed sleep, low sleep quality, split sleep, unfavourable and long working hours/shift schedules, ship movement and varying weather conditions, high noise and vibrations, constant need for alertness, health related behaviours such as smoking, exercise below prescribed levels for maintenance of healthy hearts and bodies (although the physical work is demanding), adverse health outcomes from somatic and muscular pain, and varying lengths of trips. According to Smith et al. [43] if the combination of the risk factors was six or higher, the odds ratio for fatigue was 8.85 at work and 9.07 during the rest period. Most participants in the study were exposed to 6+ risk factors throughout the trip, making us conclude that the risk of accidents constantly overshadows these workers, suggesting a significantly greater negative effect of fatigue than any of these factors taken in isolation. Furthermore, recent work conducted with workers in the offshore oil industry also reveals similar findings regarding health outcomes, showing the combined effects of fatigue indicators having a cumulative negative impact on the health and wellbeing of workers more than any other factor [54].

CONCLUSIONS

In this study, sleep efficiency scores from actigraphy ratings on the KSS and PFS were used as outcome variables to examine the association with the work environment. Hypothesis 1 was confirmed in that engine power correlated positively with sleep efficiency, but was rejected regarding sleepiness and physical fatigue as no relationship was found between the two. Hypothesis 2 was rejected, with no relationship between crew size and the outcome variables. Hypothesis 3 was confirmed, with more ship movement increasing physical fatigue and decreasing sleep efficiency but showing no relationship with KSS. Hypothesis 4 regarding the effect of noise was rejected as noise during time off positively correlated with sleep efficiency and shared no relationship to sleepiness or physical fatigue. Hypothesis 5 about the effect of shift systems was also rejected as no significant impact was revealed between the shift system and any of the outcome variables. Hypothesis 6a was confirmed, with catch-per-person-per-day showing a strong positive relationship with sleep efficiency, while hypothesis 6b was rejected, with no relationship between catch-per-person-per-day and KSS or PFS. Hypotheses 7a and 7b were confirmed, with days at sea having a positive impact on sleep efficiency and an adverse impact on KSS and PFS, thereby confirming our hypotheses.

We found that the time of day followed by ship movement were the most consistent exposure variables with the highest impact on the outcome variables. It is also noteworthy that the trip length was the only variable that revealed a relationship with all the outcome variables, either as a stand-alone or interacting with the number of sleep periods per day.

Ship variables were found to play a smaller role than expected in the current study. Nevertheless, we will not conclude that these variables don't matter as the variance between the size of fishing vessels within the same group was rather small, which could account for our findings. Only engine power was strong enough to show a relationship to sleep efficiency and seems to function as a reasonable estimate of the ship's size. Crew size did not reveal a significant effect. Again, possibly the same applies since there was minimal variation in crew size within the vessel groups and this could be the reason for it.

The trip length in days was a better measure of fatigue than days at sea per year most likely because the number of days per year variable is influenced by more external variables such as the variance in social and work obligations between trips. Neither the shift system nor the number of hours worked per day seemed to have a significant impact on the outcome variables. This finding was unexpected but we believe that it should be included in future studies. Possibly these findings were due 1) to having too small a sample and, 2) the different shift systems most often appearing together (with changes from one vessel type to the other) which, in reality, produce a lot of confounders. When comparing the mean scores on the KSS and physical fatigue, however, we found that the netting vessel crew that worked the longest hours were the ones who scored the highest on the KSS, followed by longliner fresh fish crews who worked the 6-6 system, which has been rated as the worst. The crews on netting vessels also scored highest on the physical fatigue scale; thus, it cannot be rejected that work hours and shift system do contribute to these scores. The time of day had the greatest impact on both their physical fatigue ratings and sleep efficiency, with the highest sleep efficiency being between 00:30 and 06:30.

The catch in tons per day was revealed to have a positive effect on sleep efficiency while large hauls did not impact the participants' sleepiness scores or physical fatigue. We expect the reason behind this to be the psychological processes because their paychecks depend on the catch. Thus, the more there was to do, the happier the fishers were; and their elevated psychological state combined with the hunting culture (where adrenaline increases when the hunt is good) most likely made them unaware of their tiredness. For these fishers, spending more energy and having peace of mind from knowing that the trip would pay well resulted in better sleep. Higher rankings on the fishers' physical fatigue scale were associated with greater sleep efficiency, unlike higher levels of sleepiness which did not seem to significantly impact it. Only with ship movement do these two outcome variables move in different directions owing to the impact that rolling has on sleep. Even though we did not get significant results from all our exposure variables, we believe that most of them should be included if conducting related studies in the future.

RECOMMENDATION FOR FUTURE STUDIES

Future studies to determine the influence of noise should focus on control groups and individually worn noise metres rather than merely relying on measuring stations. In the current study, we only found significant effects when analysing it as a single variable against the outcome variables despite the high noise exposures. It was also observed that fishers used earmuffs in the noisiest workstations. Interpreting the result and concluding that noise is not a problem would be a mistake, and most likely a type II error as the high dB(A) noise levels during work and time off exceeded recommendations by the Danish Maritime Authority's technical regulations which state that the daily personal noise exposure during 12 hours of work should not exceed 83 dB(A). Maximum exposure in rest areas is set to be 60 dB(A) for bedrooms, 65 dB(A) for leisure rooms and 65 dB(A) for dining rooms and living spaces. We believe that the explanation for the minimal effects observed is found in the lack of variance as all vessels scored high on noise. In view of this, we recommend that researchers in noise-exposed and loud working environments use dosimeters and make comparisons with groups in low noise-exposed working environments. They should also include a variable that takes into account the wearing of earmuffs and other noise protection gear, and whether or not they are used. We are inclined to believe that the subjective ratings of noise disturbance are reliable, as found by other authors, e.g. Hansen and Holmen (2011) [17]. The lack of effect found in this study is likely due to the limited variance in noise levels measured by the objective method and the inability to assess and monitor the use of protective aids like earmuffs.

Work environments should be designed to meet human physiological requirements and compensate for its limitations in order to ensure the wellbeing and safety of those who work at sea. Our study points to several factors that could be taken into consideration to help move toward this goal. One of the best investments would be to design and construct fishing vessels that would have reduced ship movement. Making a buffer for the increased risk of the circadian nadir by adding an extra person on the bridge during the early morning hours (when the risk of falling asleep is greatest) could improve the safety of crew and vessel. Additionally, if respite from duties for fishers is possible, we recommend that this be done preferably between the hours of 02:00 to 06:00 in order to reduce the risk of fatigue and sleepiness which inevitably increase the risk of accidents and other eventualities onboard vessels.

We hope that through this research we succeed in alerting the relevant personnel to further recognise and acknowledge the urgent need to address the health and safety issues that fatigue causes in fishers. Our sincere desire is that this study encourages dialogue on how it is influenced by individual factors and organisational practices. This, we believe, could result in finding more constructive ways to evaluate, manage, prevent or minimise fatigue and its effects amongst workers in this vital industry.

Conflict of interest: None declared

REFERENCES

1. Christiansen JM, Hovmand SR. Prevention of accidents at work in Nordic fisheries – What has worked? In: Nordic Council of Ministers. TemaNord, Copenhagen 2017.
2. Jensen OCC, Petursdottir G, Holmen IM, et al. A review of fatal accident incidence rate trends in fishing. Int Marit Health. 2014; 65(2): 47–52, doi: 10.5603/IMH.2014.0011, indexed in Pubmed: 25231324.
3. Thorvaldsen T, Kaustell K, Mattila T, et al. What works? Results of a Nordic survey on fishers' perceptions of safety measures. Marine Policy. 2018; 95: 95–101, doi: 10.1016/j.marpol.2018.06.022.
4. Wadsworth EJK, Allen PH, McNamara RL, et al. Fatigue and health in a seafaring population. Occup Med (Lond). 2008; 58(3): 198–204, doi: 10.1093/occmed/kqn008, indexed in Pubmed: 18310605.
5. Smith AP, Allen PH, Wadsworth EJK. Crew, manning and fatigue. In: Pocket D, Patraiko D (eds). Navigation Accidents and their Causes. The Nautical Institute, www.nautinst.org 2015.
6. Ricci JA, Chee E, Lorandeau AL, et al. Fatigue in the U.S. workforce: prevalence and implications for lost productive work time. J Occup Environ Med. 2007; 49(1): 1–10, doi: 10.1097/01.jom.0000249782.60321.2a, indexed in Pubmed: 17215708.
7. Barnett M, Zhao Z, van Leeuwen WMA. Project MARTHA: The Final Report. January 2017. https://doi.org/10.13140/RG.2.2.30339.30249.
8. Oldenburg M, Jensen HJ. Stress and strain among merchant seafarers differs across the three voyage episodes of port stay, river

passage and sea passage. PLoS One. 2019; 14(6): e0217904, doi: 10.1371/journal.pone.0217904, indexed in Pubmed: 31163071.
9. Silvetti A, Munafò E, Ranavolo A, et al. Ergonomic risk assessment of sea fisherman part III: manual handling and static posture. Adv Intelligent Systems Computing. 2019: 379–392, doi: 10.1007/978-3-030-20145-6_38.
10. Akerstedt T. Work hours and sleepiness. Neurophysiol Clin. 1995; 25(6): 367–375, doi: 10.1016/0987-7053(96)84910-0, indexed in Pubmed: 8904199.
11. Åkerstedt T. Shift work. Encyclopedia of Sleep. 2013: 197–201, doi: 10.1016/b978-0-12-378610-4.00040-1.
12. Breidahl T, Christensen M, Jepsen JR, et al. The influence of ship movements on the energy expenditure of fishermen. A study during a North Sea voyage in calm weather. Int Marit Health. 2013; 64(3): 114–120, indexed in Pubmed: 24072536.
13. Duncan CA, MacKinnon SN, Marais JF, et al. Energy cost associated with moving platforms. PeerJ. 2018; 6: e5439, doi: 10.7717/peerj.5439, indexed in Pubmed: 30186679.
14. Akerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. Int J Neurosci. 1990; 52(1-2): 29–37, doi: 10.3109/00207459008994241, indexed in Pubmed: 2265922.
15. Abrahamsen A, Weihe P, Fróði D, et al. Sleep, sleepiness, and fatigue on board Faroese fishing vessels. Nat Sci Sleep. 2022; 14: 347–362, doi: 10.2147/NSS.S342410, indexed in Pubmed: 35264889.
16. Åkerstedt T, Kecklund G, Axelsson J. Subjective and objective quality of sleep. Somnologie - Schlafforschung und Schlafmedizin. 2008; 12(2): 104–109, doi: 10.1007/s11818-008-0342-z.
17. Hansen JH, Holmen IM. Sleep disturbances among offshore fleet workers: a questionnaire-based survey. Int Marit Health. 2011; 62(2): 123–130, indexed in Pubmed: 21910116.
18. World Health Organization. Burden of Disease from Environmental Noise 2011; 128.
19. Costa G. Shift work and occupational medicine: an overview. Occup Med (Lond). 2003; 53(2): 83–88, doi: 10.1093/occmed/kqg045, indexed in Pubmed: 12637591.
20. Parkes KR. Age, smoking, and negative affectivity as predictors of sleep patterns among shiftworkers in two environments. J Occup Health Psychol. 2002; 7(2): 156–173, doi: 10.1037//1076-8998.7.2.156, indexed in Pubmed: 12003367.
21. Richardson G, Tate B. Hormonal and pharmacological manipulation of the circadian clock: recent developments and future strategies. Sleep. 2000; 23 Suppl 3: S77–S85, doi: http://europepmc.org/abstract/MED/10809190, indexed in Pubmed: 10809190.
22. Härmä M, Partinen M, Repo R, et al. Effects of 6/6 and 4/8 watch systems on sleepiness among bridge officers. Chronobiol Int. 2008; 25(2): 413–423, doi: 10.1080/07420520802106769, indexed in Pubmed: 18484371.
23. Short MA, Agostini A, Lushington K, et al. A systematic review of the sleep, sleepiness, and performance implications of limited wake shift work schedules. Scand J Work Environ Health. 2015; 41(5): 425–440, doi: 10.5271/sjweh.3509, indexed in Pubmed: 26103467.
24. Olafsdóttir L. The relationship between fishermen's health and sleeping habits. Work. 2004; 22(1): 57–61, indexed in Pubmed: 14757907.
25. Cole RJ, Kripke DF, Gruen W, et al. Automatic sleep/wake identification from wrist activity. Sleep. 1992; 15(5): 461–469, doi: 10.1093/sleep/15.5.461, indexed in Pubmed: 1455130.
26. Akerstedt T, Gillberg M. Subjective and objective sleepiness in the active individual. Int J Neurosci. 1990; 52(1-2): 29–37, doi: 10.3109/00207459008994241, indexed in Pubmed: 2265922.
27. Buysse DJ, Reynolds CF, Monk TH, et al. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res. 1989; 28(2): 193–213, doi: 10.1016/0165-1781(89)90047-4, indexed in Pubmed: 2748771.
28. Smets EM, Garssen B, Bonke B, et al. The Multidimensional Fatigue Inventory (MFI) psychometric qualities of an instrument to assess fatigue. J Psychosom Res. 1995; 39(3): 315–325, doi: 10.1016/0022-3999(94)00125-o, indexed in Pubmed: 7636775.
29. Wickham H, Averick M, Bryan J, et al. Welcome to the Tidyverse. J Open Source Software. 2019; 4(43): 1686, doi: 10.21105/joss.01686.
30. Read T, Files E. Package 'readxl' 2022.
31. Time TP, Date D, Implements D, Mit L, Utf LE, Kirill A, Kirill M, Date RC. Package 'hms' 2022.
32. Bates D, Mächler M, Bolker B, et al. Fitting Linear Mixed-Effects Models Using lme4. J Statistical Software. 2015; 67(1): 1–48, doi: 10.18637/jss.v067.i01.
33. Kuznetsova A, Brockhoff P, Christensen R. lmerTest Package: Tests in Linear Mixed Effects Models. J Statistical Software. 2017; 82(13): 1–26, doi: 10.18637/jss.v082.i13.
34. Package T. Package 'ordinal' 2022.
35. Linear T, Mixed N, Models E, Fit D, Hmisc S. Package 'nlme' 2022.
36. Zeileis A, Fisher J, Hornik K, et al. Colorspace: a toolbox for manipulating and assessing colors and palettes. J Statistical Software. 2020; 96(1): 1–49, doi: 10.18637/jss.v096.i01.
37. Package T. Package 'gridExtra' 2022.
38. Østergaard H, Poulsen TR, Remmen LN. Ergonomisk arbejdsmiljø, fysisk belastning og fatigue på danske fiskefartøjer. 2015. https://www.sdu.dk/-/media/files/om_sdu/institutter/ist/maritimsundhed/rapporter/ergonomisk+arbejdsmiljø+fysiske+belastninger+og+fatigue+på+danske+fiskefartøjer.pdf.
39. Boter H, Mänty M, Hansen AM, et al. Self-reported fatigue and physical function in late mid-life. J Rehabil Med. 2014; 46(7): 684–690, doi: 10.2340/16501977-1814, indexed in Pubmed: 24819423.
40. Watt T, Groenvold M, Bjorner JB, et al. Fatigue in the Danish general population. Influence of sociodemographic factors and disease. J Epidemiol Community Health. 2000; 54(11): 827–833, doi: 10.1136/jech.54.11.827, indexed in Pubmed: 11027196.
41. Dietch JR, Taylor DJ, Sethi K, et al. Psychometric Evaluation of the PSQI in U.S. College Students. J Clin Sleep Med. 2016; 12(8): 1121–1129, doi: 10.5664/jcsm.6050, indexed in Pubmed: 27166299.
42. Jepsen JR, Zhao Z, van Leeuwen WMA. Seafarer fatigue: a review of risk factors, consequences for seafarers' health and safety and options for mitigation. Int Marit Health. 2015; 66(2): 106–117, doi: 10.5603/IMH.2015.0024, indexed in Pubmed: 26119681.
43. Smith A, Allen P, Wadsworth E. Seafarer fatigue: the Cardiff Research Programme. November 2006.
44. Akerstedt T, Anund A, Axelsson J, et al. Subjective sleepiness is a sensitive indicator of insufficient sleep and impaired waking function. J Sleep Res. 2014; 23(3): 240–252, doi: 10.1111/jsr.12158, indexed in Pubmed: 24750198.
45. Lützhöft M, Dahlgren A, Kircher A, et al. Fatigue at sea in Swedish shipping-a field study. Am J Ind Med. 2010; 53(7): 733–740, doi: 10.1002/ajim.20814, indexed in Pubmed: 20187001.
46. van Leeuwen WMA, Kircher A, Dahlgren A, et al. Sleep, sleepiness, and neurobehavioral performance while on watch in a simulated 4 hours on/8 hours off maritime watch system. Chronobiol Int. 2013; 30(9): 1108–1115, doi: 10.3109/07420528.2013.800874, indexed in Pubmed: 23879695.

47. Lack LC, Lushington K. The rhythms of human sleep propensity and core body temperature. J Sleep Res. 1996; 5(1): 1–11, doi: 10.1046/j.1365-2869.1996.00005.x, indexed in Pubmed: 8795795.
48. Monk TH. Subjective ratings of sleepiness: the underlying circadian mechanisms. Sleep. 1987; 10(4): 343–353, doi: 10.1093/sleep/10.4.343, indexed in Pubmed: 3659732.
49. Oldenburg M, Jensen HJ, Latza U, et al. Seafaring stressors aboard merchant and passenger ships. Int J Public Health. 2009; 54(2): 96–105, doi: 10.1007/s00038-009-7067-z, indexed in Pubmed: 19288290.
50. Sąlyga J, Kušleikaitė M. Factors influencing psychoemotional strain and fatigue, and relationship of these factors with health complaints at sea among Lithuanian seafarers. Medicina (Kaunas). 2011; 47(12): 675–681, indexed in Pubmed: 22370467.
51. Sunde E, Bratveit M, Pallesen S, et al. Noise and sleep on board vessels in the Royal Norwegian Navy. Noise Health. 2016; 18(81): 85–92, doi: 10.4103/1463-1741.178481, indexed in Pubmed: 26960785.
52. Tamura Y, Horiyasu T, Sano Y, et al. Habituation of sleep to a ship's noise as determined by actigraphy and a sleep questionnaire. J Sound Vibration. 2002; 250(1): 107–113, doi: 10.1006/jsvi.2001.3900.
53. Hilgard ER, Atkinson RC, Atkinson RL. Introduction to psychology. 8th Ed. Harcourt Brace Jovanovich, 1983.
54. McNamara R, Smith A. Combined effects of fatigue indicators on the health and wellbeing of workers in the offshore oil industry. J Health Med Sci. 2020; 3(3), doi: 10.31014/aior.1994.03.03.122.